

Magnetic Cortical Activities Associated with Linear and Circular Vection

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ABSTRACT

The sensation of apparent self-motion (vection) is a common visual perception, from which neurophysiological interferences about visual-vestibular interaction can be drawn. Studies in monkey and human have identified regions of the cerebral cortex that receive vestibular inputs, such as the posterior part of the insula (parieto-insular vestibular cortex: PIVC), vicinity of the intraparietal sulcus and the superior temporal gyrus; however, cortical areas which are involved in vection are still unclear. In this study, we recorded magnetoencephalography (MEG) to elucidate cortical activities associated with linear vection (LV) and circular vection (CV). In LV and CV conditions, oscillatory activities were enhanced in the frequency range 0.03-3.0 Hz, but declined within the frequency range of 6.0-14.0 Hz, in which α , μ , and τ activities are included. These synchronizations and desynchronizations with vection may reflect activities of the cortical area around the insula, temporal and parietal lobes. Also, minimum norm estimation showed activities of the posterior insula, the intra-parietal sulcus, and superior temporal gyrus evoked by LV as well as CV. The results suggest that the cortical areas that receive vestibular inputs are activated by LV and CV, and integrate multi-modal information.

KEY WORDS

Vection, Vestibular cortex, Synchronization, Desynchronization, Minimum Norm Estimation, Magnetoencephalography,

INTRODUCTION

Vestibular stimuli invariably lead to a sensation of body motion. However, visual motion always has two perceptual interpretations: either self-motion or object-motion. The sensation of apparent self-motion (vection) is a common visual perception, from which neurophysiological interferences about visual-vestibular interaction can be drawn. Since the vestibular system can sense only accelerations, the detection of self-motion at a constant velocity depends entirely on visually induced vection. Electrophysiological studies in monkeys have identified regions of the cerebral cortex that receive vestibular inputs, such as the posterior part of the insula (parieto-insular vestibular cortex: PIVC), portions of the intraparietal sulcus (IPS) (area 2v), the superior temporal gyrus (STG), and the central sulcus (area 3aV) [Guldin, 1988]. In humans, studies using patients and non-invasive measurements have shown the contributions of the IPS, the STG, and the posterior insula [Friberg, 1985, Bottini, 1994, Nakagawa, 2002]. However, it is not clear which cortical areas are involved in vection. In this study, we recorded brain magnetic fields to elucidate cortical activities associated with linear vection (LV) and circular vection (CV).

METHODS

STIMULI: Four conditions of visual motion stimuli were projected onto a screen subtended 110 degrees by 74 degrees (Fig. 1): (A) dots accelerating in radial directions to a focus of convergence in the middle of the screen (backward LV); (B) dots accelerating in different direction (no-LV); (C) dots circulating counterclockwise around the middle of the screen (clockwise CV); (D) dots circulating counterclockwise around different points (no-CV). Each condition consisted of a black background and a total of 100 white dots.

SUBJECTS: Ten healthy volunteers (8 males and 2 females, 22-41 years, right-handed, normal or corrected-to-normal vision) took part in this study. Subjects were carefully selected and were trained prior to the experiment to experience vection for stimuli A and C; and all subjects had reported that they experienced vection during measurements. Subjects were requested to fixate binocularly on a central point on the screen from a distance of 60 cm and press button when he/she did not experience vection during measurements.

MEG MEASUREMENTS: Measurements of magnetic fields were carried out using a 122ch whole-head neuromagnetometer (Neuromag-122™, Neuromag Ltd., Helsinki, Finland) in a magnetically shielded room. Magnetic data were sampled at 400 Hz after being band-pass-filtered between 0.03 and 100 Hz, averaged more than 100 times. Any responses coinciding with magnetic signals exceeding 3,000 fT/cm and/or a vertical EOG deflection beyond 150 μ V were rejected from further analysis. The averaged responses were digitally low-pass-filtered at 30 Hz. The analysis time was 1.0 s from 0.2 s prior to the stimulus onset. An average 0.2 s pre-stimulus period served as the baseline.

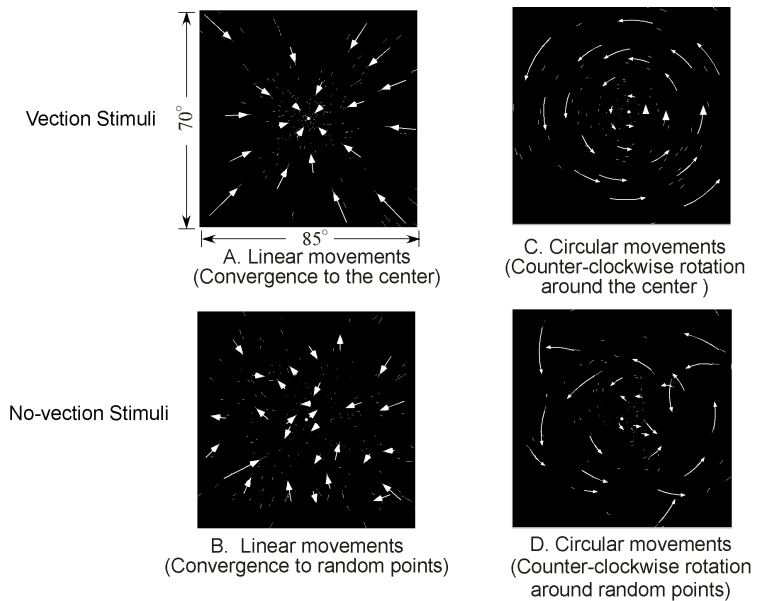


Figure 1. Four conditions of visual motion stimuli. Subjects experienced linear vection for stimulation A and circular vection for stimulation C.

EXPERIMENT I: Spontaneous magnetic fields were recorded during each visual motion stimulation. Each stimulation was set at a constant velocity during recordings: A and C: 4.2 deg/s (visual angle, average of all dots), B and D: 40 deg/s (rotation angle, average of all dots). Frequency analyses were applied to the magnetic data to look for modulations of the oscillatory activities.

EXPERIMENT II: The velocities of visual motion stimuli increased by 100% for 3.0s occasionally. Intervals of velocity-increases were set at 9.0 - 11.0s. Event-related magnetic fields triggered by the velocity increase were recorded for each visual motion stimulation. A minimum norm estimation (MNE) method was applied to the evoked data, and statistical evaluations (voxel-by-voxel paired-T tests) were carried out between LV and no-LV, and between CV and no-CV conditions to estimate details of regions specific to vection.

RESULTS

Subjective intensities of vection in conditions A and C were almost identical (A:C = 1.0:1.03).

Figure 2 shows the results from experiment I. Oscillatory activities within the frequency range of 6-14 Hz, in which α , μ , and τ activities are included, were significantly smaller in conditions A and C than that in B and D in the temporal and parietal regions. On the other hand, larger activities in the frequency range 0.03-3 Hz were observed in conditions A and C compared to B and D.

In experiment II, MNE analysis showed significantly enhanced activities for both LV and CV in the posterior insula, STG, and in the vicinity of IPS. No systematic differences were observed between conditions A (LV) and C (CV).

DISCUSSION

We showed that low-frequency oscillations (0.3-3.0 Hz) were synchronized, but that α , μ , and τ oscillations (6.0-14 Hz) were desynchronized in the temporal and parietal region when subjects experienced LV or CV. Low-frequency oscillations were observed during higher-functional activities in association cortices [Rämä, 1995, Nakagawa, 1999]. Also, some studies have reported that sensation stimuli desynchronize oscillations in the sensory cortex, e.g., α -oscillations in the visual cortex were desynchronized by auditory input [Williamson, 1997]. Therefore, it is suggested that the synchronizations and desynchronizations in the temporal and parietal regions observed in this study reflect activities associated with the processing of vection. Also, MNE analysis showed significantly enhanced activities in the posterior insula, STG, and in the vicinity of IPS by LV as well as CV. These regions are identical to the areas indexed as vestibular cortex by the previous studies in humans. The results indicated that the cortical areas that receive vestibular inputs processed sensations of vection. It is also suggested there is higher-functional interaction among these areas, which integrate multi-modal information.

ACKNOWLEDGEMENTS

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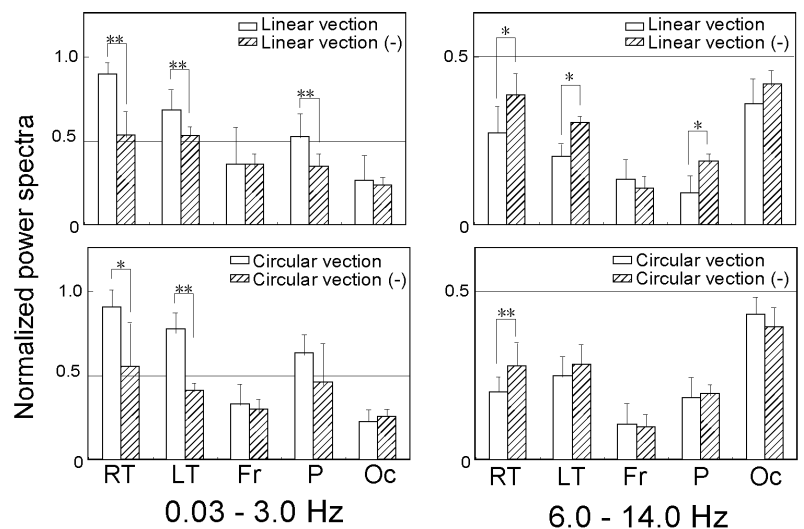


Figure 2. Oscillatory activities for four conditions of visual motion stimuli. RT: right temporal region, LT: left temporal region, Fr: frontal region, P: parietal region, Oc: occipital region.